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No. 13606

Evaluation of NDI Compressed Air Foam System (CAFS) Applied as a Retrofit

August 1994

By Samuel Duncan

U.S. Army Tank-Automotive Command
Research, Development and Engineering Center
Warren, Michigan 48397-5000

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Army Engineer Firefighting Detachments require increased firefighting capability to compensate for deficiencies in structural, brush, or wildland and large petroleum storage site fires. Additionally, Army fire departments responsible for protection and prevention on posts, camps and stations have difficulty accessing new or emerging technology do not possess state-of-the-art equipment. The results of this evaluation and subsequent projects, will be reported throughout the Army in an attempt to mitigate operational deficiencies and widen the scope of knowledge in the Army fire service.

The evaluation of non-developmental retrofitted compressed air foam systems show an efficiency of suppressive capabilities of water superseded by water alone. Retrofitting the equipment was not easy or inexpensive but it was very successful.

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The project was accomplished by the members of the CRADA with the cooperation of their respective organizations. Those personnel and their organizations are as follows:

Mr. Samuel Duncan, Principal Investigator
US Army Belvoir Research, Development & Engineering Center

Dr. Homer W. Carhart, Director of Safety and Survivability
US Naval Research Laboratory

Deputy Chief Kenneth Jones
Captain Gary Pope
Fairfax County Fire and Rescue Department

Assistant Chief Tom White
Fort Belvoir Fire Department

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Section I Introduction

BACKGROUND

Engineer Firefighting Detachments require improved fire suppression capability to provide exposure protection from radiant heat, increase discharge distance of fire streams and reduce water requirements when fighting fires in a tactical or undeveloped theater.

Engineer Firefighting Detachments organized as an LB Team, Fire Truck, must be capable of successfully containing and suppressing Class A or structural fires as well as Class B or liquid petroleum fires. The single fire truck authorized this unit uses water only for Class A fires and water and military specification Aqueous Film Forming Foam (AFFF) for Class B fires. The quantity of water and type of equipment authorized for Class A fires is inadequate for exposure protection of structures and firefighting. The quantity of water and AFFF and type of equipment authorized is inadequate to fight the size of Class B fires in Army petroleum facilities such as the Fuel System Supply Points (FSSP) and Tactical Petroleum Terminals (TPT). The unit does not have sufficient water and AFFF to provide exposure protection in Army petroleum facilities. Host nation support and infrastructure required for fire fighting are either unavailable or incompatible with Engineer Firefighting Detachments equipment.

Research has established that water is 5-10% effective as a fire suppressant in Class A or structural fires, when used in the form of a water stream [Dr. Haessler, Walter M., *The Extinguishment of Fire,* 1974]. This means that where 100% of the water in a fire stream is discharged onto burning fuels only 5-10% provides a suppressant or extinguishing effect. About 90% of the water discharged in a Class A fire bounces off the fuel resulting in run-off. Water damage in structural fires amounts to about 80% of the total damage. It is imperative to make water more effective. Class A foams appear to improve the effectiveness of water in structural firefighting by reducing the surface tension of the water which improves its ability to cool.

AFFF, developed to replace protein foams for use against Class B fires, requires a minimum application rate of 0.1 gallons per minute per square foot of liquid fuel surface. It was designed to spread across a flat surface of burning fuel forming a film, which acts as a barrier between the fuel vapors and oxygen. Water then drops out of the foam cooling the fuel substrate. AFFF requires replenishment to insure the fire stays out. It provides no more exposure protection to a nearby facility or tank than a continuous flow of water because, like water, the foam solution runs off.

No single technology available on the market provides exposure protection, increases the discharge distance and reduces water requirements better than Compressed Air Foam Systems (CAFS) without substantially increasing the size and weight of firefighting equipment. Since Class A and Class B foams behave similarly when generated through standard equipment they should be comparable when generated through CAFS.

In late 1992, the Fuel and Water Quality Team of the Belvoir Research, Development and Engineering Center (BRDEC) met with the Fairfax County Fire and Rescue Department, Fairfax, Virginia, to develop a plan to procure, retrofit, evaluate and demonstrate the efficacy of an off-the-shelf CAFS applied to an in-service structural fire truck. The project was designed to executed in two phases to evaluate CAFS capabilities in Class A and Class B fires.

BRDEC's Fuel and Water Quality Team wrote the CRADA document providing the legal framework for the project and procured the necessary equipment for retrofitting an in-service fire truck with CAFS technology. Fairfax County furnished a truck for the retrofit. The Naval Research Laboratory was contacted and agreed to provide a live fire Class B burn facility at their Chesapeake Bay Detachment and instrumentation to measure heat and gases for both phases. Fort Belvoir Fire Department provided several buildings of similar size and materials for crew training and the final demonstration for the Class A phase.

It should be noted that CAFS technology is available from several companies. CAFS is configured for large fire trucks, as drop-in units for pick-up trucks and stand-alone units. Despite documentation establishing the increased effectiveness and safety of CAFS technology and it's modest cost, the fire service has been slow to endorse this technology.

This report describes an Army initiated cooperative effort to compare CAFS technology to a standard AFFF fire stream on a collapsible liquid petroleum tank fire at the Naval Research Laboratory's Chesapeake Bay Detachment on 4-5 October 1993. Also described in the report is a comparison of CAFS to a standard fire stream in structural fire tests conducted at Ft. Belvoir, Virginia, 3-5 November 1993 and a characterization of the feasibility of retrofitting in-service fire trucks with CAFS technology.

OBJECTIVES

The objectives of the evaluation were to:

1. Evaluate CAFS firefighting capabilities compared to AFFF in liquid petroleum fire suppression and water in structural fire suppression.
2. Determine the feasibility of retrofitting in-service fire trucks with CAFS.
3. Demonstrate the three primary technological advantages of CAFS:
   - Increased cooling of exposed or burning materials by adhering to vertical surfaces
   - Increased discharge range
   - Reduced water requirements

The evaluation was not intended to be an operational test of Army equipment currently in the inventory or intended for acquisition. It was not intended to evaluate the firefighting capability of foams. CAFS is not a foam, it is a method of generating foam. For further information on the performance of Class A foams in structural firefighting see the report issued by Tank-Automotive Research, Development and Engineering Center entitled Report of Class A Foams (Project 93NK24320/NC222) prepared by Underwriters Laboratories Inc.

DESCRIPTION OF CAFS

Compressed Air Foam Systems, or CAFS, was described in a British engineering handbook in 1941. The US Navy explored the concept in 1947 but it did not catch on. In the 1970's the Texas Forest Service brought CAFS to the fire service for wildland applications to expand water in arid environments. The concept converted 250 gallons of water into 2500 gallons of finished foam. In the simplest terms CAFS is water and foam concentrate mixed as foam solution in a standard water pumping system with compressed air injected into it downstream of the pump.

There are three characteristics of CAFS that make it desirable for Engineer Firefighting Detachments as well as other firefighters: 1) ability of the foam to cling to vertical surfaces, 2) increased discharge distance, and 3) reduced water requirements. No other technology currently available offers these characteristics to the Engineer Firefighting Detachments or to the fire service.

CAFS offers regulated air flow resulting in a wide variety of foam types to suit the particular type or size of fire. Less air injected into the system produces a wetter foam, more air produces a drier foam. The drier foam loses discharge distance but clings readily to virtually any surface for as much as 3 days unlike standard foam solution on water alone which strikes the burning fuels and runs off providing minimal cooling.

DESCRIPTION OF THE EQUIPMENT

An Emergency-One 1,000 gallon per minute (gpm) (see Figure 1) structural pumper with a Hale pump was provided by Fairfax County Fire and Rescue Department. Hale Fire Pump, Inc. provided a list of components for retrofitting CAFS technology. Hale also provided various smaller fittings and parts throughout the retrofit process to ensure quality compressed air foam. Modifications to the pump panel (see Figure 2) and installation of the CAFS was accomplished by the Fairfax County Fire and Rescue Department maintenance department. Below is a list of the components recommended by Hale:

1. 160 CFM rotary vane type, 125 psi, Hale HVC air compressor including air filter, oil filter, air-cooled oil radiator with hydraulic-driven fan, and Hale CAFS control with auto pressure regulator.
2. Hale/Foampro 2001 Automatic foam proportioning system for direct injection with paddlewheel flow meter.
3. Foam link automatic foam relay.
4. Bronze 2-1/2 inch and 3-1/2 inch static mixing chambers.

A hot-shift type power take-off (PTO) was fitted to the pumper to power the air compressor. Digital gages were fitted to the pumper for accurate readings of gallons per minute of water and foam flow, pump pressure, cubic feet of air per minute and totalizers for total water and foam concentrate consumption.

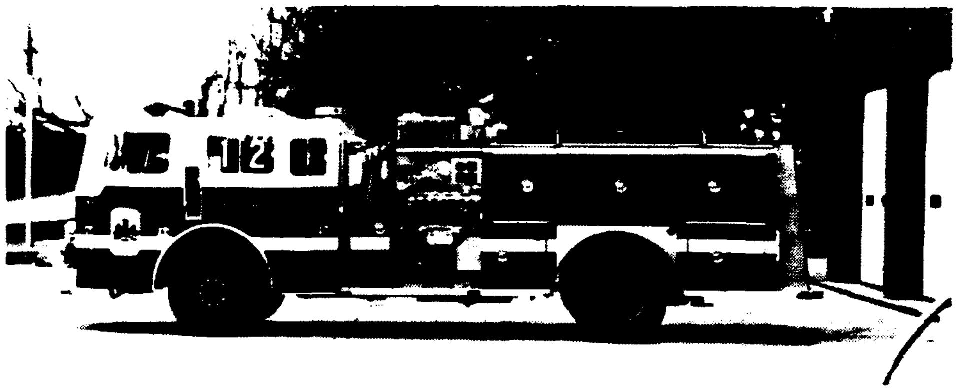

Figure 1. Fairfax County Pumper

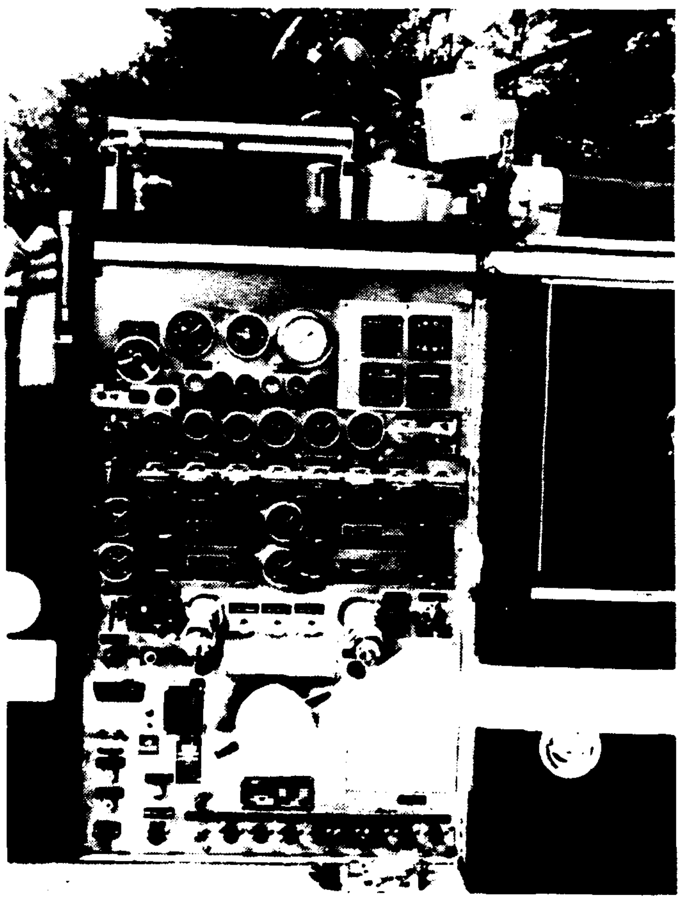

Figure 2. Pump Panel

Section II Application Procedures

LIQUID PETROLEUM TANK FIRE (CLASS B)

On October 4-5 1993 the project members met at the Naval Research Laboratory's Chesapeake Bay Detachment to conduct an evaluation of CAFS' ability to provide exposure protection for collapsible Bulk Fuel Tank Assemblies (BFTAs) used by the Army Quartermaster troops operating a 3.8 million gallon Tactical Petroleum Terminal (TPT).

The collapsible fabric tanks used for fuel storage in the TPT are manufactured to military specification MIL-T-53066A of elastomeric-coated nylon fabric. If a BFTA is ignited the resulting fire would be about 10,000 square feet in size with fuel in depths of up to 5 feet. The fuel type could range from diesel fuel to JP-4, a highly volatile jet fuel that is being phased out but still exists. The Army does not possess the fire fighting equipment necessary to extinguish a fire of this magnitude. This deficiency is magnified when it occurs during operations against a hostile force in an undeveloped country. Figures 3 and 4 show three TPTs set up on a beachhead and one collapsible tank..

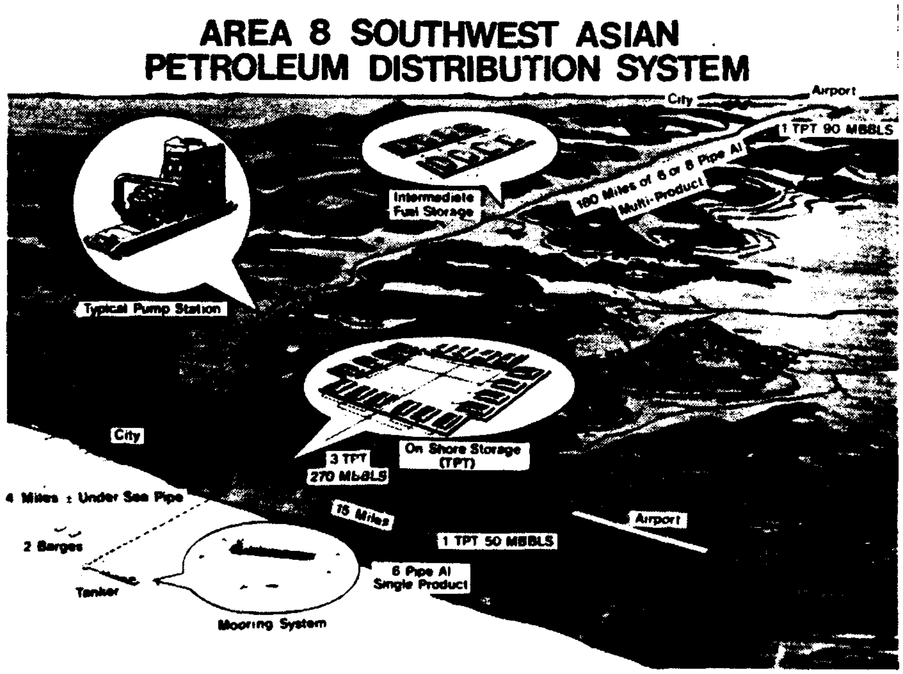

Figure 3. Shore-Based Tactical Petroleum Terminals

Figure 4. Bulk Fuel Tank Assembly

The collapsible petroleum tank live fire test burns were performed by Hughes Associates, contracted by the Navy to operate the CBD facility. All standard Navy safety precautions and procedures were used.

On 4 October distance tests were conducted and some fine tuning of the apparatus was accomplished (see Figures 5 and 6). Distances observed were in the range of 110 to 120 feet with a wet foam. The system was unable to dry the foam (see Figure 7) to the degree required but coating characteristics were fairly good. Live burns were to be conducted the next day. Comparison of the protection provided by CAFS and a fire retardant cloth is in Table 1.

Table 1. Class B Fires

Live Fire	Pre-burn Time	Protection Provided	Time to Defeat	Percent Gain
1	20 seconds	None	10 seconds	
2	116 seconds	CAFS	90	800%
3	30 seconds	FR Material	16 seconds	60%
4	30 seconds	CAFS	119 seconds	1,090%

On 5 October the first objective was to determine how quickly radiant heat might destroy a collapsible fuel tank when a nearby tank is fully involved. A portion of the tank material approximately 10 feet wide by 15 feet long was cut from the tank, including the breather vent assembly and the drain and filler-discharge assembly and placed over

several concrete bricks. The tank gave the appearance of being filled to a height of about 10 inches (see Figure 8) A bermed area, approximately 10 feet square and immediately adjoining the tank material, was constructed and filled with 25 gallons of JP-5. The fuel was cleaned and replenished for each of 4 burns.

The first burn (see Figures 9 and 10) confirmed that the tanks have no resistance to fire. The pit next to the tank material was ignited, allowed to free burn for about 20 seconds until the pit was fully involved. Within 10 seconds of full involvement of the pit the tank was melted, fully defeated and incapable of holding fuel. A full tank would have ruptured under the pressure of holding 210,000 gallons causing fuel to flow suddenly against its berm possibly spilling over the berm. Radiant temperatures 2 feet from the burning fuel were about 1,100°F.

For the second tank fire AFFF from the CAFS equipped pumper was applied before the burn (see Figure 11). The pit was ignited. Due to shifting winds a preburn of 116 seconds was required for full involvement. The CAFS system exhibited a slug effect until a 3rd section of 1 1/2 inch hose was added. Although the slug effect lessened, the flow was not smooth. Additional air was added which caused the foam to dry out somewhat but it would not cling or adhere to the tank material. It slid slowly off the tank, instead leaving a visible residue. Despite this technical difficulty CAFS provided sufficient protection to prevent destruction for just over 90 seconds after full involvement of the pit. A gain of 800% over the first burn.

For the third tank fire a piece of fire resistant (FR) textile manufactured by Springs Protective Fabrics was spread over the tank material. The material has non-combustible gas imbedded in the fibers which are released when exposed to flame. Radiant heat began slowly destroying the tank material in 12 seconds. Full defeat of the tank was accomplished in 16 seconds. This is a gain of about 60% over the first burn (see Figure 12).

For the fourth tank fire the pit was ignited and the tank material was covered with AFFF generated by the CAFS equipped pumper (see Figure 13). The foam was drier than the first CAFS burn and prevented destruction of the tank material for 119 seconds from full involvement of the pit. This showed a gain of approximately 1,090%.

Despite equipment difficulties, later resolved in the Fairfax County maintenance facility, inferior CAFS foam, unable to cling to the tank material, showed significant increases in time to ignition due to radiant heat exposure.

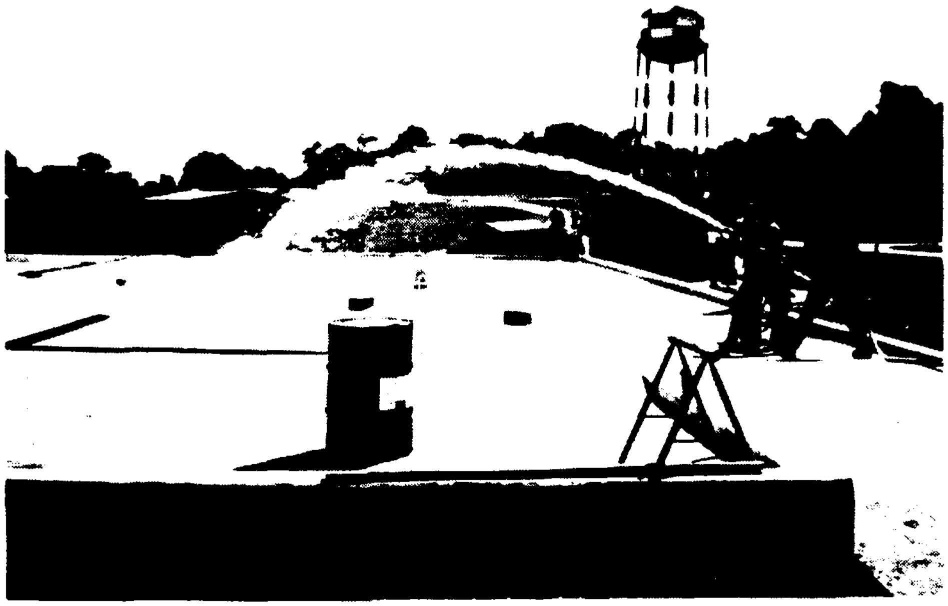

Figure 5. Distance Test at Naval Research Lab (Water)

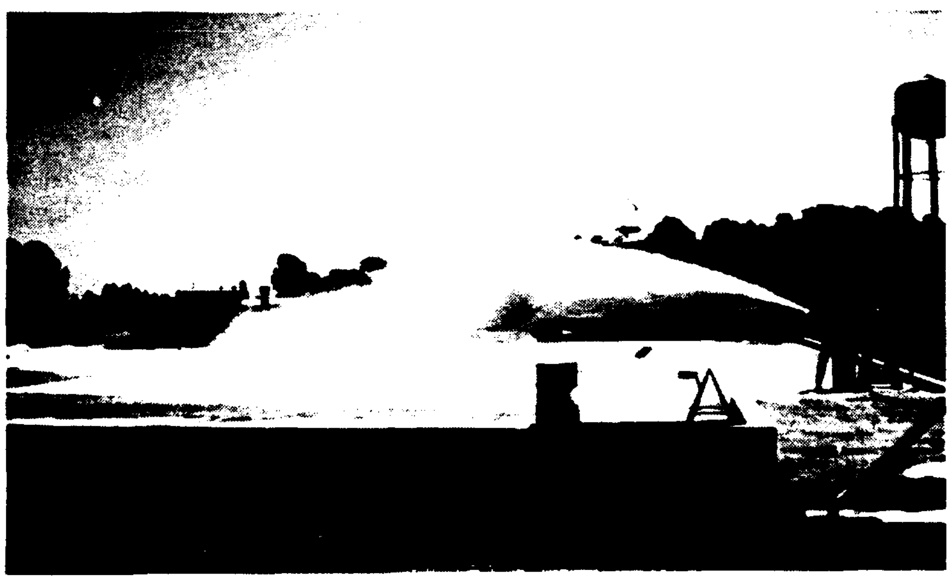

Figure 6. Distance Test at Naval Research Lab (CAFS)

Figure 7. Dry Foam

Figure 8. Tank/Fuel Pool

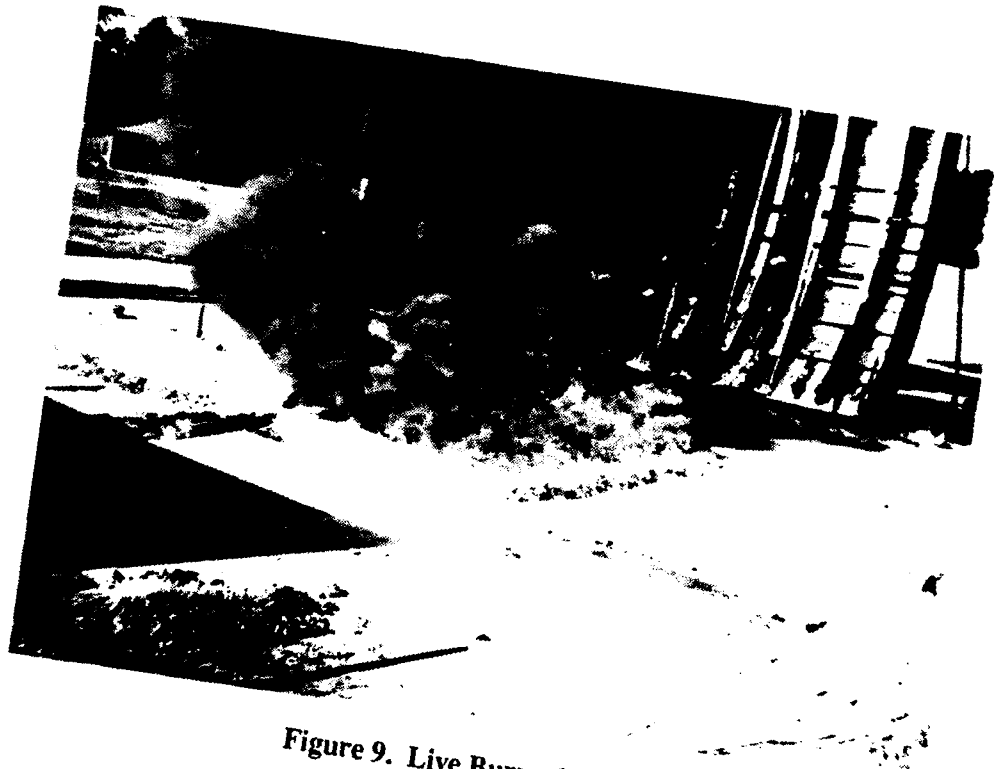

Figure 9. Live Burn of Tank

Figure 10. Destroyed Tank

Figure 11. Tank with CAFS Foam

Figure 12. Tank with CAFS Foam

Figure 13. Live Burn of Tank with CAFS Foam

STRUCTURAL FIRES (CLASS A)

Structural application of CAFS was conducted in support of the Engineer Firefighting Detachments structural mission as well as for Army fire departments organized under a Table of Distribution and Allowances (TDA), Fairfax County and US Navy requirements for improved firefighting capability. All hardware problems experienced during the Class B phase were resolved by Hale technicians and Fairfax County maintenance personnel. Subsequent foam generation ranged from a dry, snow-like foam with extremely well developed ability to cling to vertical surfaces, to wet, soupy but still exhibiting a tendency to cling or run slowly (Figure 14). Changing the foam from dry to wet required no more effort than turning a dial to increase air.

Application procedures were in accordance with Fairfax County Fire and Rescue Department Standing Operating Procedures for structural training fire^. Fairfax County fire crews were given safety briefings and a synopsis of the characteristics of CAFS.

The structures used for the scoping and full scale tests were identical two-story World War II vintage barracks buildings. For two days evolutions were conducted in these buildings by several crews. Each evolution consisted of two fires, the first extinguished with water, the second with CAFS. After water was used charred fire loading materials were removed and water swept out. New materials were brought in and ignited. After a CAFS applications reignition for the area burned was much more difficult than after a water application. Foam was still present in the first buildings the following morning. CAFS generated foam held water on the walls, ceiling and floor long enough for significant absorption to occur.

Figure 14. CAFS on the Walls

SCOPING AND FULL SCALE TESTS

The buildings were equipped with thermocouples to record temperature rise and fall. Fire loading was accomplished with 2A and 3A cribs, bales of hay, box springs and wooden pallets. Each attack was conducted using a 1 3/4 inch hand line. Several training evolutions were conducted for familiarization with CAFS. The equipment used, air flow, and pressures are described in Table 2 and live fire data is recorded in Table 3 at the end of this section.

On the first day water was applied through 3/4 inch smooth bore tip at 124 gallons per minute (gpm). CAFS was applied using a 1 3/8 inch smooth bore tip at 50 gpm with 50 cfm of air. Data for the first day's water test showed 95 gallons of water required to effect knockdown versus 35 gallons used in the CAFS evolution. Preburn for the water test was 116 seconds versus 382 in the CAFS evolution. Despite a much longer burn resulting in a more deeply seated fire, 64% less water was required.

On the second day, with flames blowing out of the first floor windows (see Figure 15), 157 gallons of water was required to achieve knockdown versus 63 gallons with CAFS.

Rookies and their more experienced colleagues expressed positive impressions of CAFS. Comments ranged from "better than water" to exclamations of incredulity. A 2 1/2 inch line rather than the usual 1 3/4 inch was used with a 2 inch smooth bore tip with a flow of 110 gpm and 110 cfm of air. Despite the larger size hose, handling of the line was much improved with CAFS over water.

Figure 15. Live Burn in Two-Story Buildings

DEMONSTRATION TESTS

For the demonstration test on 5 November two one-story buildings, positioned side by side, were used. Before the burns were conducted a distance comparison was made of a water stream flowing 50 gpm at 50 psi and a CAFS stream at the same rate. The water stream discharged about 40 feet. The CAFS sent foam capable of coating a wall or tree nearly 100 feet (see Figure 16).

The first building was extinguished with water after a preburn of 186 seconds (see Figure 17). Temperatures at 3 feet above the floor were approximately 900° F. Total heat flux was 80 kW/m2. Knock down was accomplished in 53 seconds using 47 gallons of water.

The second building was extinguished using the CAFS after a preburn time of 660 seconds. The fire was much more severe than the first building. Temperatures at 3 feet above the floor were 1600° F or 44% hotter than the first building. The fire was attacked from the rear of the building, down a hallway and into the main room where the fire had been ignited. Knockdown was accomplished in 24 seconds or 60% less time. The amount of agent required was 21 gallons or 55% less water (see Table 2).

Figure 16. Distance Test at Ft. Belvoir

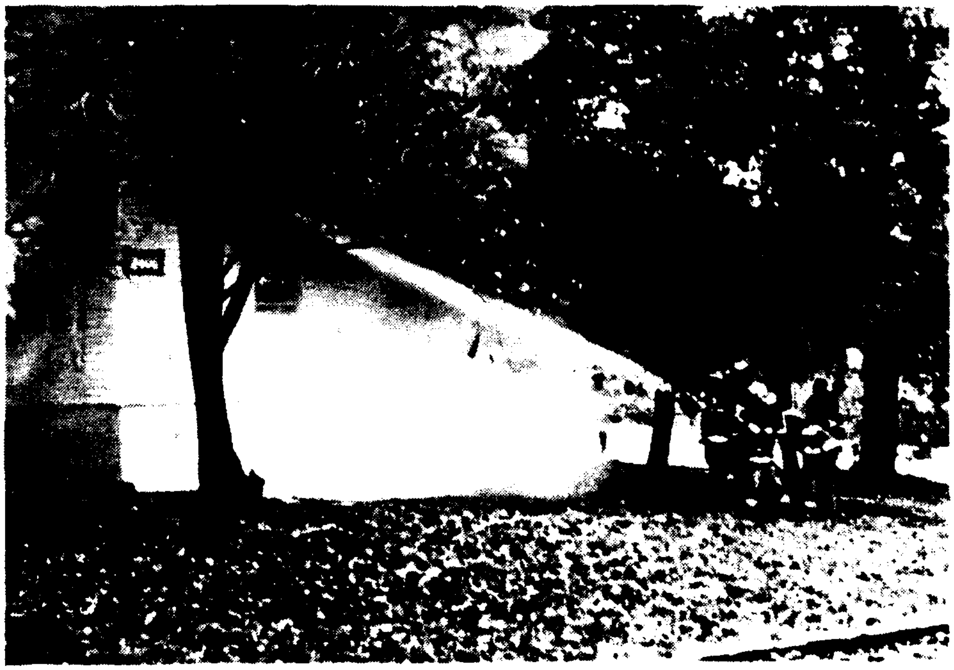

Figure 17. Live Burn at Fort Belvoir (Water)

Table 2. Technical Data for Class A Structural Tests

PLEASE GIVE UNITS IN WHICH MEASURED (e.g., psig)	SCOPING TESTS 11/03/93		FULL SCALE TESTS 11/04/93		DEMO TESTS 11/05/93	
	Water	Foam	Water	Foam	Water	Foam
AIR PRESSURE (units?)	—	125 psi	—	125 psi	—	125 psi
AIR FLOW RATE* (units?)	—	50 cfm	—	50 cfm	—	50 cfm
WATER PRESSURE (units?)	55 psi/. N.P.	125 psi E.P.	50 psi/ N.P.	125 psi E.P.	50 ps/i N.P.	125 psi E.P.
NOZZLES USED	$^{3}/_{4}$" S.B.	$1^{3}/_{8}$" S.B.	$^{1}/_{2}$" S.B.	$1^{1}/_{8}$" S.B.	$^{1}/_{2}$" S.B.	$1^{1}/_{4}$" S.B.
LENGTH OF HOSE (in between pumper & nozzle)	200'	200'	200'	200'	200'	200'
DIAMETER OF HOSE	$1^{3}/_{4}$	$1^{3}/_{4}$	$1^{3}/_{4}$	$1^{3}/_{4}$	$1^{3}/_{4}$	$1^{3}/_{4}$

**We already have water flow rates as shown in the other summary table attached.*

Table 3. Results of Full-Scale Tests Using Water Only and Compressed Air Foam

	SCOPING TESTS 11/03/93		FULL SCALE TESTS 11/04/93		DEMO TESTS 11/05/93	
	Water	Foam	Water	Foam	Water	Foam
FIRE COMPARTMENT SIZE Floor Area (Length x Width, ft) Floor to Ceiling Height (ft)	 20x29, 10x12[1] 8, 8		 47x29 8		 32x19 10	
FUEL LOADING						
#2A Cribs	2	2	2	2	2	2
#3A Cribs	1	1	1	1	1	1
# Pallets	31	31	12	12	28	28
# Box Spring Mattress	4	4	0	0	2	2
# Bales Hay	3	3	2	2	3	3
AGENT FLOW RATE (gpm)	124	50	124	50	53	53
PREBURN TIME (sec)	116	382	84	90	186	660
MAXIMUM TEMPERATURES (°F)						
at ceiling level	925	990	1400	1400	1400	1700
3 ft above floor level	780	860	880	500	900	1600
MAXIMUM HEAT FLOW (kW/m^2)	NDR	NDR	65	55	80	204
GAS ANALYSIS						
% O_2 (minimum)	NDR	NDR	NDR	NDR	7-9	7-9
% CO (minimum)	NDR	NDR	NDR	NDR	>1.8	>1.8
% CO_2 (minimum)	NDR	NDR	NDR	NDR	>4.3	>4.3
FIREFIGHTING TIME TO ACHIEVE KNOCKDOWN (sec)	46	42	76	76	53	24
AMOUNT OF AGENT USED TO ACHIEVE KNOCKDOWN (gal)	95	35	157	63	47	21

[1]A single large area with an additional room off of this area was used

NDR= No Data Recorded

Section III Feasibility Evaluation

FEASIBILITY OF RETROFITTING CAFS

Retrofitting CAFS to an in-service pumper appears to be too costly in terms of dollars and time; the apparatus is out of service during the retrofit. Three experienced, motivated maintenance personnel with virtually unlimited equipment had a great deal of difficulty over a 6 month period applying the equipment recommended. It might have proved less costly to gut the pumper by removing the pump, tank and the plumbing, including drive train, to rebuild the pumper with the necessary components for CAFS.

There cannot be a recommendation for retrofitting CAFS technology to in-service Army apparatus without a pre-configured kit that can be quickly and efficiently applied to provide CAFS capability.

FEASIBILITY OF CAFS

The CAFS technology was evaluated in a Class B and a Class A scenario. Despite initial equipment difficulties the capability of CAFS generated AFFF to effect exposure protection for fire threatened collapsible fuel tanks was significant. CAFS generated foam in structural fire fighting compared to water proved to be far superior. In all evolutions CAFS proved to be capable of knocking the fire down faster, using less water, reducing the weight of the hose and increasing discharge distance over standard equipment. The foam could be made to stick to overhangs, vertical surfaces such as walls, and to ceilings thereby improving the cooling effect of the water. The CAFS generated foam successfully exhibited all three primary technological characteristics and provided superior fire suppression and protection.

The results of the evaluation are a strong recommendation for CAFS technology, whether for use in TDA fire departments protecting post, camps and stations, municipal fire departments or the Engineer Firefighting Detachments.

Section IV Conclusion

The results of the CRADA support two conclusions. The first is retrofitting CAFS technology to in-service Army fire trucks is not cost effective without a complete, easy-to-install kit. If a kit is developed it should be a "universal" type, capable of fitting the myriad of fire trucks in the Army inventory. No kit exists at this time.

The second conclusion is that CAFS technology provides firefighters with much improved capability to fight fires by increasing the distance of discharge, reducing water requirements and increasing the cooling ability of water by causing the foam to adhere to burning or exposed fuels. Hose line weight is significantly reduced thus mitigating one of the primary physical stressors of fire fighting. Fire trucks could be smaller without losing total firefighting capability. CAFS technology can be built into new trucks for about 15% of the base truck price.

Section V Recommendations

Based on the results and conclusions of this evaluation, it is the unanimous recommendation of the project members of the CRADA that CAFS technology would significantly improve the performance of most fire trucks and should be considered in all future fire truck procurements. The technology is simple enough when engineered into the truck at the outset of design, and effective enough in extinguishing fires to be of great value. The performance of CAFS could be improved by additional research to refine or improve the characteristics of CAFS.

NOTES AND OPINIONS

There is no question that additional research is required to bring firefighting into the 21st century. We are still fighting fires in the same manner as when fire was discovered - lots and lots of water. We are not questioning the role of water as the chief agent for fire suppression, rather its effectiveness as it is being used. Conclusive proof from many legitimate sources such as the National Fire Protection Association, Factory Mutual Research Corporation and others, show 80% of the damage in a fire is caused by the massive amounts of water rather than the fire. The deaths and injuries associated with fire incidents are directly attributable to the fire. We must find a better way. We can learn it the hard way on the fire ground, incident by incident; or we can learn through the agent of research.

The CAFS characteristics result in reduced costs and increased safety for any fire department. For the Engineer Firefighting Detachment's worldwide mission, reducing the amount of water required is critical. These firefighting soldiers have the ability to protect and deploy forces but lack appropriate equipment.

The project members are in accord regarding the importance technology must play in fire protection. The fire service, Department of Army or civilian sector, has traditionally been slow to accept change giving rise to the adage "150 years of dedicated service unhampered by progress". Fire departments can no longer rely on the proximity and availability of another engine company when they get into trouble. Fire departments and emergency personnel can no longer rely on unending budget streams, either. They can no longer knock the door down and pummel the contents with hose streams pushing 250 gallons per minute at 125 psi. The handwriting is on the wall - becoming more efficient, effective and safer isn't a better way to do business, it is the only way to stay in business.

Our conclusions, particularly the second, should not be construed to indicate that Army fire departments can operate with less personnel or that fewer firefighters would be required on the fire ground where CAFS equipment is present. Fires in structures designed for living or those that have high occupancy, require four firefighters - one at the pump panel, two on the hose and one to direct the operation and otherwise assist in rescues, hose lays or the myriad of actions that may be necessary to save lives and protect property from fire damage.

There is no question that CAFS reduces water requirements and provides faster knockdown. There is no question that CAFS also prevents reignition as well as initial ignition of exposures. Sadly, there is no question that education of personnel involved in this very special and dangerous field, at all levels, is urgently needed to prevent the loss of one more building, the loss of one more valuable acre of wildland and the loss of one more precious life.

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US Army Materiel Command
ATTN: AMCDCG-A (Dr. Oscar)
5001 Eisenhower Avenue
Alexandria, VA 22333-0001

2 Commandant
US Army Engineer School and Ft. Leonard Wood
ATTN: ATSE-CDS-P (MAJ Harshbarger)
ATTN: ATSE-CDS-P (SSG Fox)
FT. Leonard Wood, MO 65473-6620

1 Director
Directorate of Facilities & Housing
ATTN: DAIM-FDF-B (Mr. Park)
Casey Building
Fort Belvoir, VA 22060

2 Commander
Naval Research Laboratory, Code 6180
ATTN: Dr. Carhart, 4555 Overlook Avenue,
SW, Washington D.C.

5 Fairfax County Fire and Rescue Department
Administrative Services Division
ATTN: Deputy Chief Kenneth Jones
4100 Chain Bridge Road
Fairfax, VA 22030

3 Director
Directorate of Public Works
ATTN: Chief Shelton & Chief White
Ft. Belvoir Fire Department
Ft. Belvoir, VA 22060-5606

2 Commander
CASCOM
Modernization and Technology Division
ATTN: ATCL-MEC-F (Chris Parent)
10500 A Avenue
Ft. Lee, VA 23801-6000

15 U.S. Army Tank-Automotive RD&E Center
Mobility Technology Center
Fuels and Water Supply Division
Fuels and Water Quality Team
Fort Belvoir, Virginia 22060-5606

1 Visual Information Spt Division
ATTN: ASQT-FBR-S (L. Paradis)
Ft. Belvoir, VA 22060